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Analysis of ACPW-to-Microstrip Transition with ANN-MRTD Method

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Abstract

This paper combines artificial neural network technique with the MRTD method (ANN-MRTD) and give detailed illustration of this method. The MRTD equation is embedded into training algorithms of the artificial neural network. A novel asymmetrical coplanar waveguide (ACPW) to microstrip transition is proposed, different center frequency of transition can be obtained by adjusting dimension of ACPW. The transition is analyzed with ANN-MRTD method, and the results are provided. The correctness and effectiveness of ANN-MRTD method are verified by the results.

Keywords: MRTD, ANN, ACPW, transition.

1 Introduction

Coplanar waveguides (CPWs) have predominantly been used in microwave and millimeter-wave integrated circuits. Since C. P. Wen advanced CPW [1], a lot of scholars have been interested in it. There are many researches about CPW, the application of CPW was studied by many scholars in recent years. Such as broadband directional coupler and monopole antenna and filters were designed by microstrip and coplanar waveguide [2]-[4]. The most of them are given only for symmetric CPW, there are few literatures published about the asymmetric coplanar waveguides (ACPWs).The asymmetric coplanar waveguide (ACPW) is flexible and general compared with CPW, and the symmetric lines can be considered as the special cases of asymmetric lines. So the study of ACPW is actually important.

In recent years, the ACPW was studied using many techniques such as mapping technique, FDTD method and wavelet method [5]-[7]. 2005, Rabindra K.Mishra combined artificial network technique with traditional FDTD technique to compute electronic and magnetic problem [8]. In this paper, the multi-

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resolution time domain (MRTD) is combined with artificial neural network (ANN) to analysis a novel ACPW-to-microstrip transition.

2 ANN-MRTD Method

According to Maxwell's equations

$$\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} \tag{1}$$

$$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \tag{2}$$

The electric and magnetic fields are expanded using MRTD method as followed:

$$\begin{aligned} {}_{k+1}E^{\phi z}_{l,m,n+1/2} &= {}_{k}E^{\phi z}_{l,m,n+1/2} + \frac{\Delta t}{\varepsilon \Delta x}\sum_{i=L}^{L-1} a(i)_{k+1/2}H^{\phi y}_{l+1/2+i,m,n+1/2} \\ &- \frac{\Delta t}{\varepsilon \Delta y}\sum_{i=L}^{L-1} a(i)_{k+1/2}H^{\phi x}_{l,m+i+1/2,n+1/2} \end{aligned} \tag{3}$$

$$\begin{aligned} {}_{k+1}H^{\phi z}_{l+1/2,m+1/2,n} &= {}_{k}H^{\phi z}_{l+1/2,m+1/2,n} - \frac{\Delta t}{\mu \Delta x}\sum_{i=L}^{L-1} a(i)_{k+1/2}E^{\phi y}_{l+i,m+1/2,n} \\ &+ \frac{\Delta t}{\mu \Delta y}\sum_{i=L}^{L-1} a(i)_{k+1/2}E^{\phi x}_{l+1/2,m+i,n} \end{aligned} \tag{4}$$

We define that an ANN can represent the $\boldsymbol{E}_z$ field, with one output node for the $\boldsymbol{E}_z$ field and four input nodes as independent variables *l*, *m*, *n*, and *k* similar to RBF neural network, this three-layered Feed forward net work uses a mean-variance type connection for input to hidden layer (Fig.1).

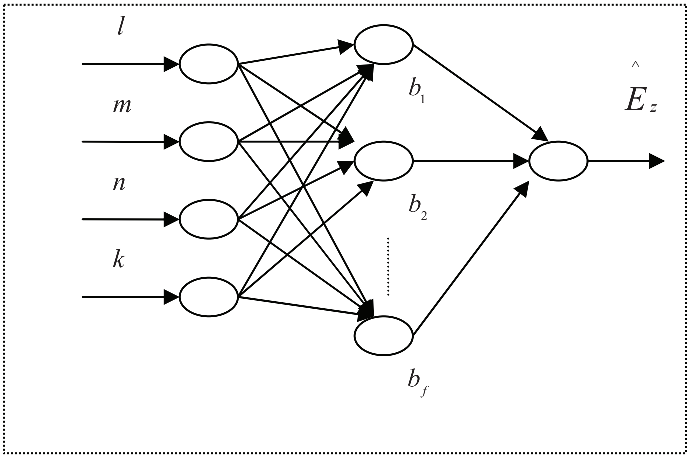

Fig. 1. Schematic of network structure

The network output $\hat{E}_z(l,m,n,k)$ is the approximation for $\boldsymbol{E}_z$, given as [8]:

$$\hat{E}_z(l,m,n,k+1) = \sum_{f=1}^{F} b_f(l,m,n,k+1) w_f \tag{5}$$

$$b_f(l,m,n,k+1) = g[r_f(l,m,n,k+1)] \tag{6}$$

$$r_f(l,m,n,k+1) = \sum_{h=1}^{4} \left(\frac{w_{hf} - a_h}{v_{hf}}\right)^2 \tag{7}$$

$$g(x) = \exp\left(\frac{-x}{2}\right) \tag{8}$$

The mean and variance connection strengths between the *h*th input neuron and *f*th hidden neurons are u_{hf} and v_{hf} respectively. The connection strength between the *f*th hidden neuron and output neuron is w_f. Similarly, a_1, a_2, a_3, a_4, correspond, respectively, to l, m, n, and k.

Training a network consists of adjusting its weights using a training algorithm. In this paper, the field is zero at the boundary. The neural model is trained with BP learning algorithms. The training algorithms adopted in this study optimise the weights by attempting to minimise the sum of squared differences between the desired and actual outputs, namely:

$$J = \frac{1}{2} e^2(l,m,n,k+1) \tag{9}$$

$$e(l,m,n,k+1) = E_z - \hat{E}_z(l,m,n,k+1) \tag{10}$$

$\boldsymbol{E}_z$ can be obtained from equation (3-5). The adjustment is carried out over several training iterations until a satisfactorily small value of J is obtained or given number of iteration is reached.

3 Application to ACPW-microstrip Transition

The major effort until now has been directed at CPW to microstrip transition. However, the same emphasis has not been expended on broadband ACPW to microstrip transition. This paper discloses a broadband ACPW to microstrip transition on the base of [9]. The structure of transition is shown in Fig.2.

The proposed transition is printed on the Arlon DiClad 880 substrate with dielectric constant of 2.2 and a thickness of 0.254 mm. The folded balun consisting of open/short circuits with one quarter-wavelength long is employed for field and impedance matching simultaneously. The new ACPW to microstrip transition is designed at the center frequency of 5.5 GHz. The characteristic impedance of the microstrip is chosen to be 100 ohm. In the simulation, the transition is excited by time domain voltage waveforms as followed:

$$\psi = \exp[-(n\Delta t - 200\Delta t)/(100\Delta t)]^2 \tag{11}$$

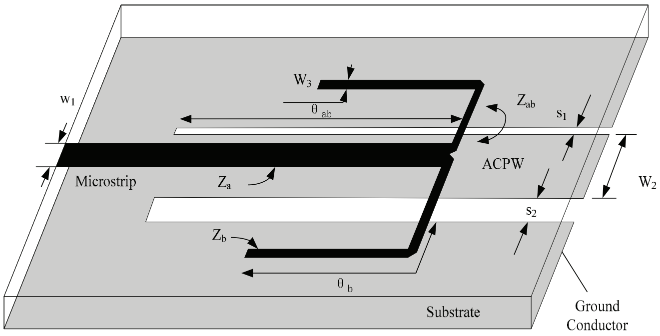

Fig. 2. ACPW to microstrip transition.

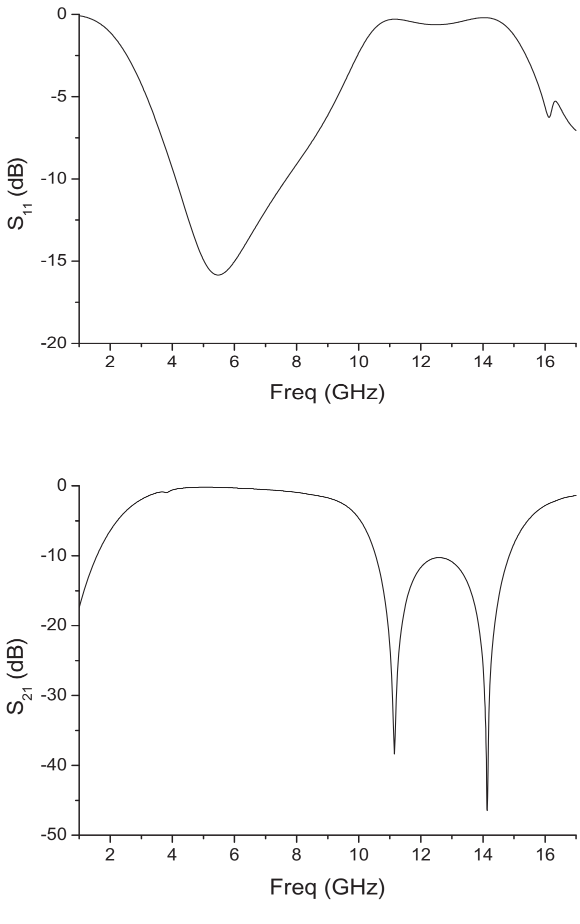

Fig. 3. Return and insertion loss of transition.

In order to obtain a wider transition bandwidth, intensive numerical simulation using ANN-MRTD method has been made to determine the dimension of ACPW. The geometric parameters of transition are shown in Tab. 1.

Tab. 1. Parameters of transition

parameters	value	parameters	value
W_1 (mm)	0.76	S_1 (mm)	0.05
W_2 (mm)	3.40	S_2 (mm)	0.10
W_3 (mm)	0.22	ε_r	2.2

The simulated insertion and return losses of the proposed transition are shown in Fig.3. Compared with reference [9], we can adjust the dimension of ACPW to get the aimed center frequency. This design is simple to implement and allows easy insertion. Because of its excellent bandwidth, it is immediately recognized as a viable method for transferring power between ACPW and microstrip media.

4 Conclusion

A new method that combines artificial neural network technique with the MRTD method (ANN-MRTD) is proposed, and detailed illustration of this method is given. The MRTD equation is embedded into training algorithms of the artificial neural network. A novel asymmetrical coplanar waveguide (ACPW) to microstrip transition is proposed and analysed with ANN-MRTD method. The correctness and effectiveness of ANN-MRTD method are verified by the results. Compared with reference [9], we can adjust the dimension of ACPW to get the aimed center frequency.

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